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During the last reporting period, important progress has been made in the system for both the object tracking and anomalous behavior algorithms. We have completed significant enhancements to the background color modeling that improves both the efficiency and performance of the overall system, allowing more consistent and robust object tracking and anomalous behavior detection. In addition, we have completed several data collection programs, including efforts that will support analysis for multi-camera analysis as well as combined video and acoustic tracking capabilities. SIG has also completed an initial implementation of our real-time analytics framework that can support the testing process. Further motivation for developing real-time video analytics is the desire to transition this technology into fielded systems.

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1 Summary

The purpose of this program is to address the development of algorithms for adaptive processing of multi-sensor data, employing feedback to optimize the linkage between observed data and sensor control. The envisioned multi-modal adaptive system is applicable for intelligence, surveillance, and reconnaissance (ISR) in general environments, addressing base and port security, as well as urban and suburban sensing during wartime and peace-keeping operations. Of significant importance for current and anticipated DoD activities, the ISR system is designed to detect asymmetric threats, with the goal of recognizing unusual behavior or activities. Technologies and systems developed under this effort will be designed for semi-automated scene awareness, with the objective of recognizing behavior that appears atypical (e.g. atypical object motion, and dynamic characteristics of people and vehicles). Leveraging our previously developed technology, SIG is developing second-generation methods to adaptively learn the statistics of dynamic object behavior in video, while focusing on defining system requirements for sensor deployment by using field data (vs. highly controlled indoor data). SIG is also working closely with its subcontractor, Lockheed Martin, to integrate additional technologies, such as object classification and recognition, to provide a more robust and discriminative system. Additionally, SIG is cooperating with the Navy's China Lake facility to collect representative data for a deployed system, and to specify requirements and features necessary of such a system. Finally, SIG is coordinating with Integrian on prototype development schedules and product integration requirements, and defining a joint marketing and commercialization strategy for such products.

2 Technical Developments

During the last reporting period, important progress has been made in the system for both the object tracking and anomalous behavior algorithms. We have completed significant enhancements to the background color modeling that improves both the efficiency and performance of the overall system, allowing more consistent and robust object tracking and anomalous behavior detection. In addition, we have completed several data collection programs, including efforts that will support analysis for multi-camera analysis as well as combined video and acoustic tracking capabilities. SIG has also completed an initial implementation of our real-time analytics framework that can support the testing process. Further motivation for developing real-time video analytics is the desire to transition this technology into fielded systems.

2.1 Tracking Algorithms

SIG has continued to test and stabilize the tracking algorithm. Modeling improvements have been made to the shape and color models for computational efficiency and robustness across varying environments. In particular, SIG has implemented and tested a novel approach to the background color modeling that has improved both the efficiency and the performance of the overall system. This novel approach for the background

model is able dynamically track a changing background color distribution through the use of multiple hypothesis testing based on previous background pixel observations.

The incorporation of this new background modeling approach has dramatically improved the performance of the object detection and tracking systems relative to other approaches. This novel approach is not present in the literature on the subject and has resulted in better object identification and tracking due to the improved fit of the background color model distribution with observed background data, particularly in scenes with complex and/or dynamic background features (such as trees swaying the wind or variable lighting conditions). In addition, the new multi-hypothesis background model approach has resulted in better object tracking due to more robust object identification and assignments when there are color occlusions between the background and moving foreground objects.

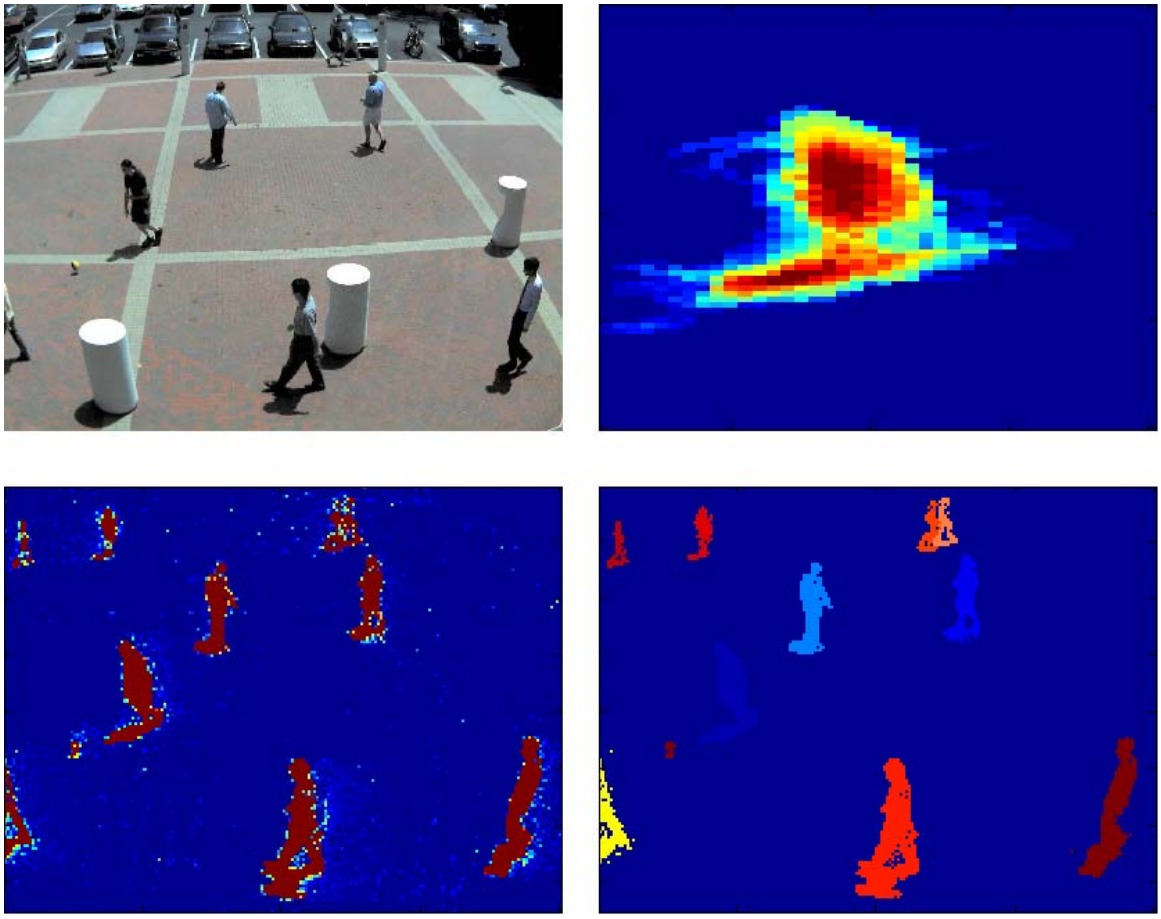

Figure 1: Improved Background model based multi-hypothesis approach results in better fit to dynamic background color distributions and provides better tracking performance in complex dynamic scenes.

2.2 Anomalous Behavior Analysis

One of the key improvements SIG has introduced into the system in the previous reporting period the ability to detect anomalous behavior. Over a short training period, an

anomalous behavior model is trained for "normal" behavior; that is, behaviors that are likely to be seen based upon observed object positions and speeds. We have continued to refine this approach and have begun to analyze models where the decisions about anomalous behavior can be based on the total behavior history of the tracked object as opposed to making decisions based simply on estimates of current velocity and position. As these more complete models of object activity are refined, we will be able to make more sophisticated judgments about anomalous behavior. At the same time, the system will still be able to learn typical behaviors directly from the data, and characterize anomalies as any deviation from this expected activity - without the need for periodic behavior rule updates.

2.3 Multi-Sensor Data Collections Completed

During this last reporting period, SIG has worked with AFRL to complete a multi-camera video data collection effort. The data collection site has been designated at the Air Force Research Laboratory facility, Building 620 and surrounding vicinity situated on Wright-Patterson AFB, OH. The data collection was designed to support multi-camera video analysis using our existing analytics framework. The data collected included over 134 hours of high-resolution video data, collected over a three-day period. The data collection was designed to capture pedestrian and vehicular traffic over a variety of different lighting and weather conditions, including both daytime and nighttime. The data was collected using four video cameras sited with partially overlapping fields-of-view to support analysis of object tracking across multiple video streams.

In addition to the multi-camera data collection, we have also collected initial dual-mode data collection whereby the SIG video analytics will be paired with adaptive acoustic array data. The data collected will be post-processed to demonstrate a capability to simultaneously track an object and beam-form an acoustic array to listen to that object as it moves through the field of view. .

2.4 Sensor Management

SIG has begun initial design of the sensor management capabilities that will help achieve our high level project goal of employing feedback to optimize the linkage between observed data and sensor control. Our goal is to implement an approach that creates the framework necessary for SMA that provides multiple levels of resolution for different processing functions. In addition, this same framework will be useful as we extend the same concept to additional types of sensors or processing regimes that are controlled by the low level object detection and tracking engine to extract even more information about the objects of interest that are being examined in the process of asymmetric threat detection.

2.5 Real-Time Implementation

SIG has made considerable progress its real-time implementation efforts. While these are not in-scope with respect to specific C2CS contractual deliverables, this real-time

capability provides for accelerated testing and performance assessment on large quantities of data. SIG has converted all of the core object detection and tracking algorithms to efficient C code implementations while maintaining the appropriate functional interfaces to SIG's other Matlab-based object behavior analysis code. SIG is also investigating high performance sensor platforms that can provide hardware and DSP-based acceleration for the core analytics modeling algorithms, as well as supporting to capability for critical modeling tasks to access sensor data at full resolution before any compression effects or artifacts are introduced.

3 Programmatic Developments

During the last performance period, SIG hosted a meeting for the C2CS project sponsors and key members of the research teams. The meeting was held on July 24, 2007 at the offices of Signal Innovations Group (SIG), in Durham, NC and attendees included Drs. Behzad Kamgar-Parsi and Ken Shaw from ONR; Lawrence Carin, Paul Runkle and Matt Welborn from SIG; Abhijit Mahalanobis from Lockheed Martin; and Alan Van Nevel from NAVAIR. This meeting included summary presentations of the current research from all teams as well as plans for the remaining contract period. In addition, this meeting provided an occasion to discuss proposals for the Year 3 option of this C2CS project as well as opportunities for possible transition of the technology, so that the research may be further enhanced and progress closer to other DoD critical applications. One particular transition opportunity is the DARPA Large Area Coverage Optical Search-While-Track and Engage (LACOSTE) project. That program is now completing Phase I, and it is deemed that much of the technology developed under this current SBIR program may be transitioned to that DARPA project. Future Directions

As already noted, the key technologies developed under this C2CS project are very relevant to the DARPA LACOSTE effort. Particular technologies that that have been developed under this program and that are of interest for LACOSTE are: (i) automated tracking of multiple targets through complex scenes, including maintenance of multiple hypotheses through occlusions; (ii) adaptive learning and removal of complex background characteristics; (iii) learning statistical models for ``normal" behavior; and (iv) development of sensor-management concepts that adaptively exploit the full sensor capabilities, through the directed acquisition of data to minimize model and hypothesis uncertainty. A more detailed plan of possible research directions for Year 3 of this C2CS effort has been prepared and submitted to ONR in August 2007. These proposals would help to not only support current C2CS objectives, but also position the technology to other efforts such as DARPA LACOSTE program.